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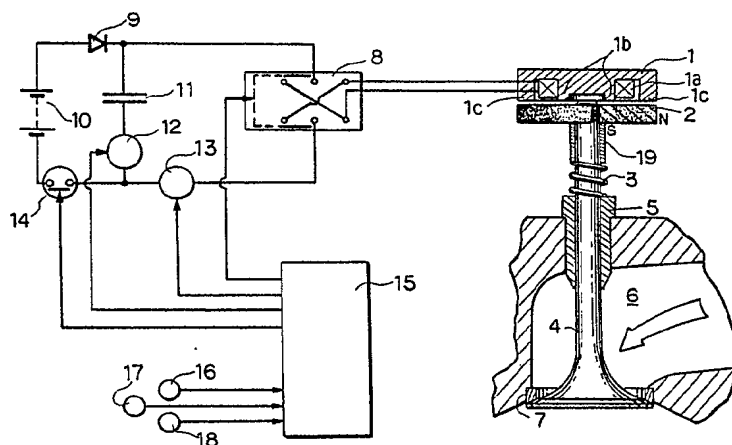
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**Electromagnetic-force valve-driving apparatus.**

(57)

A valve-driving apparatus for opening and closing an intake/exhaust valve (4) of an engine includes a permanent magnet (2) connected to the valve and a fixed electromagnet (1), attractive and repulsive forces driving the valve. A battery (10) normally drives the electromagnet (1), but if/when a strong electromagnetic force is required, current from a charge accumulating capacitor (11), charged from the battery, is used to energise the electromagnet. Control is exercised to increase or decrease the energisation of the electromagnet by the battery and the charging of the capacitor depending on the engine speed or load.

Fig. 1



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## ELECTROMAGNETIC-FORCE VALVE-DRIVING APPARATUS

This invention relates to an electromagnetic force valve driving apparatus which opens and closes the suction/exhaust valve of an engine by an electromagnetic force produced by an electromagnet.

In an ordinary engine, a valve is controlled to open and close so that a cylinder may perform a suction/exhaust operation.

In one example of a drive apparatus for opening and closing such a suction/exhaust valve, a cam shaft, which is obtained by disposing cams for suction and exhaust on one shaft, is provided on the upper portion of the engine or on one side face thereof. A crankshaft, which is the rotary shaft of the engine, and the cam shaft are connected by rotary transmission means such as a belt, and the cam shaft is driven rotatively in synchronism with the rotational phase of the engine. The axial end face of the valve is pushed by the cam face of the cam shaft via a link mechanism such as a rocker arm or pushing rod. The suction/exhaust valve normally is held in the closed state by a spring and its axial end face is opened by being pushed.

In another example of a drive apparatus for opening and closing a suction/exhaust valve, a suction cam shaft having a suction cam and an exhaust cam shaft having an exhaust cam are disposed on the upper portion of an engine, the cam face of the suction cam shaft pushes the axial end face of the suction valve directly, and the cam face of the exhaust cam shaft pushes the axial end face of the exhaust valve directly, thereby opening the suction/exhaust valve.

This conventional drive apparatus for opening and closing the suction/exhaust valve results in a large-size engine because the cam shaft and link mechanism must be added onto the engine. Furthermore, since the cam shaft and link mechanism are driven by the output shaft of the engine, some of the engine output is consumed by frictional resistance when the cam shaft and link mechanism are driven. This diminishes the effective output of the engine.

Further, the actuation timing of the suction/discharge valve cannot be altered during engine operation. Since the valve actuation timing is adjusted so as to attain high efficiency in a case where the engine is running at a prescribed rpm, engine efficiency declines when it is running at an rpm different from the prescribed rpm.

In order to solve the foregoing problems, an apparatus for driving a suction/exhaust valve to open and close the same by electromagnetic force from an electromagnet, without relying upon a cam shaft, has been disclosed in Japanese Patent Ap-

plication Laid-Open (KOKAI) Nos. 58-183805 and 61-76713.

However, these two publications do not disclose current control for suitably regulating electromagnetic force to the required magnitude in cases where a large current must be supplied to the electromagnet, as when the suction/exhaust valve starts to be moved in the opening direction and when it is decelerated just before being seated. Consequently, it is not possible to generate a sufficiently large electromagnetic force needed to smoothly start and decelerate the valve.

The present invention has been devised for the purpose of controlling a suction/exhaust valve by electromagnetic force so that the valve may be opened and closed smoothly.

In the valve driving apparatus according to the present invention, a permanent magnet connected to a suction/exhaust valve is attracted to or repelled from a fixed electromagnet opposing the permanent magnet, thereby controlling the opening and closing of the suction/exhaust valve. When it is necessary for a strong repulsive force to be applied to the suction/exhaust valve at the start of the valve opening operation and immediately before valve seating, the fixed electromagnet is supplied with electric power resulting from a charged capacitor having a low internal resistance, whereby the strong repulsive force is caused to act upon the suction/exhaust valve.

Features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings.

Fig. 1 is a block diagram illustrating an embodiment of the present invention, and

Fig. 2 is a view showing the direction in which a current is passed through a coil.

An embodiment of the present invention will now be described in detail with reference to the drawings.

Fig. 1 is a block diagram illustrating a driving apparatus according to the present invention.

Numerical 4 denotes a suction valve consisting of a light-weight, heat-resistant and high-strength ceramic. It is also permissible to form the suction valve 4 from a metal material which exhibits excellent heat resistance and high strength.

The suction valve 4 is axially supported by a valve guide 5 so as to be free to move in the axial direction, and has an axial end portion on the periphery of which an annular permanent magnet 2 is affixed.

The permanent magnet 2 is magnetized so that its inner circumferential side is an S pole and its

outer circumferential side an N pole. A collar 19 and a spring 3 are interposed between the permanent magnet 2 and the valve guide 5. The beveled portion of the permanent magnet 2 is in intimate contact with a valve seat 7 to close the suction port at the terminus of an intake conduit 6.

Disposed above the permanent magnet 2 is an electromagnet 1 having an internal magnetic pole 1b opposing the S pole on the inner circumferential side of the permanent magnet, and an external magnetic pole 1c opposing the N pole on the outer circumferential side of the permanent magnet. A coil 1a which, when excited, produces the inner pole 1b and the outer pole 1c, is wound on the electromagnet 1.

The coil 1a is connected to a changeover switch 8. In response to an externally applied signal, the changeover switch 8 changes over the energizing direction of electric power supplied to the coil 1a.

The changeover switch 9, a diode 9, a switch 14 and a controller 13 for controlling the amount of energization are serially connected to a battery 10. A point intermediate the diode 9 and changeover switch 8, and a point intermediate the energization controller 13 and the switch 14, are connected by a series circuit composed of a controller 13, which is for controlling an amount of charging, and a capacitor 11.

The charging controller 12 and energization controller 13 are both for variably controlling the amount of energization in dependence upon the valve of engine rpm and the size of the engine load in response to signals from a control unit 15.

The changeover switch 8, switch 14, energization controller 13 and charging controller 12 are connected to the control unit 15. Applied as inputs to the control unit 15 are an output signal from a timing sensor 16 for sensing crank angle, namely the rotational phase of the engine, and output signal from a rotation sensor 17 which senses engine rpm, and an output signal from a load sensor 18 which senses engine load from the amount of fuel supplied to the engine.

The control unit 15 includes, in addition to an input/output interface for supervising input/output of the aforementioned signals, a ROM in which a program and data are stored in advance, a CPU which performs processing under the control of the program stored in the ROM, a RAM for temporarily storing input signals and results of processing, and a control memory for controlling the flow of signals within the control unit 15.

The operation of the apparatus according to the invention will now be described.

Fig. 2 is a view showing the relationship between the direction in which energizing current is passed through the coil 1a and time elapsed from

the moment at which the suction valve 4 is opened. In Fig. 2, elapsed time T is plotted along the horizontal axis and the direction of the energizing current is plotted along the vertical axis. The + direction, which is that along the vertical axis above the horizontal axis, is the direction of a current which will produce an electromagnetic force in a direction to open the suction valve 4, while the - direction, which is that along the vertical axis below the horizontal axis, is the direction of a current which will produce an electromagnetic force in a direction to close the suction valve 4. The curve indicated by the broken line corresponds to a so-called "cam profile curve" and indicates the open/closed state of the suction valve 4.

Prior to the moment at which the suction valve 4 begins operating, the switch 14 is closed and current is passed into the coil 1a in one direction, namely in a direction which will produce the N pole at the internal magnetic pole 1b and the S pole at the external magnetic pole 1c, via the changeover switch 8. As a result, an attractive force acts between the electromagnet 1 and the permanent magnet 2.

The amount of energization is controlled by the controller 13. Accordingly, the electromagnetic force generated by the electromagnet 1 attains a prescribed strength. In concurrence with the above-described energization of the coil, electric power from a battery 10 charges the capacitor 11. The amount of charging is controlled by the controller 12. When it attains a prescribed amount, charging of the capacitor 11 ceases.

When the crank angle sensed by the timing sensor 16 coincides with the timing at which the suction valve 4 begins operating, namely that at which the valve is opened, as obtained from the output signals of the rotation sensor 17 and load sensor 18, the control unit 15 outputs a signal to change over the changeover switch 8 so that the energizing current flowing through the coil 1a is reversed and caused to flow in the + direction. Also, the limitation on the current applied by the energization controller 13 is removed and a resistance-less state is established. The switch 14 is opened immediately after this change in state is made.

When this is done, the charge that has accumulated in the capacitor 11 flows into the coil 1a. Though the energization controller 12 applies a current limitation in the charging direction, it does not do so in the discharging direction. In addition, the capacitor has a low internal resistance. Consequently, the discharge takes place instantaneously. Since a large current therefore flows into the coil 1a, the electromagnet 1 applies a strong repulsive force to the permanent magnet 2.

At a time  $t_1$  at which a first set time period

elapses from a time I at which the suction valve 4 opens, the control unit 15 changes over the changeover switch 8 to return the energizing current flow to the -direction, and closes the switch 14.

Since an attractive force acts between the electromagnet and the permanent magnet 2 by virtue of the foregoing operation, the speed at which the suction valve 4 moves in the opening direction is reduced and the valve is stopped. When the action of the attractive force is continued even after the suction valve stops, the valve starts to move in the closing direction. Though the amount of energization is controlled by the controller 13, it is unnecessary for the amount of energization to be made the same as that which prevailed during the time the valve was kept closed prior to time I.

The capacitor 11 is charged just as described above also when the current is flowing in the -direction after time II.

At a time III at which a second set time period elapses from time II, the control unit 15 changes over the changeover switch 8 again so that the energizing current is made to flow in the + direction, and the switch 14 is opened so that a current will flow into the coil 1a from the capacitor 11, thereby applying a repulsive force to the permanent magnet 2. As a result of this operation, the speed of the suction valve 4 in the closing direction is reduced.

At a time IV at which a third set time period elapses from time III, namely at a moment just before the suction valve 4 is seated, a change is made to an energizing state similar to that which prevailed when the suction valve 4 was being held closed prior to time I, and the valve is held in the closed state until the next timing at which the valve is opened.

The first, second and third set time periods mentioned above are obtained by storing a table, which gives the relationship between each set time and engine rpm and load, in the ROM in advance, and computing the time periods from engine rpm sensed by the rotation sensor 17 and the engine load sensed by the load sensor 18.

A map giving the relationship between engine rpm and valve opening timing is stored in the ROM in advance, and valve opening timing is altered with a change in engine rpm, whereby engine output and efficiency can be raised over the entire region of engine rpm.

In a case where an engine is composed of a plurality of cylinders, it is possible to perform cylinder control to increase or decrease the number of operating cylinders by driving or stopping the suction/exhaust valves of each valve attendant upon a rise or fall in engine rpm.

Though an embodiment of the present invention has been described primarily with regard to a

suction valve, it is obvious that the drive apparatus according to the invention can be similarly applied to an exhaust valve.

## Claims

1. An electromagnetic-force valve-driving apparatus for opening and closing an intake/exhaust valve (4) of an engine, the apparatus comprising: a movable permanent magnet (2) connected to an axial end portion of the valve; a fixed electromagnet (1) having fixed magnetic poles (1b,1c) opposing the poles of the permanent magnet;

timing decision means (15,16,17,18) for detecting rotational speed and load of the engine and determining valve opening/closing timing corresponding to the rotational speed and load;

valve control means (8,9,10,13,14) for energising the fixed electromagnet in accordance with the timing determined by the timing decision means; and

charge accumulating means (11) for storing up a charge which energises the fixed electromagnet when the valve is opened and closed.

2. Apparatus according to claim 1, further including charging control means (12) for increasing or decreasing the amount of charging of the charge accumulating means dependent on engine speed or load.

3. Apparatus according to claim 1 or claim 2, wherein the charge accumulating means (11) is a capacitor.

4. Apparatus according to any of claims 1 to 3, wherein the movable permanent magnet (2) is annular in shape.

5. Apparatus according to any of claims 1 to 4, wherein a pair of magnetic poles (1b,1c) of the fixed electromagnet oppose respective north and south poles of the permanent magnet (2).

6. Apparatus according to any of claims 1 to 4, wherein the valve is formed of a ceramic material.

7. Apparatus according to any of claims 1 to 6, further including

control means (12) for increasing or decreasing the amount of energisation of the electromagnet by the battery dependent on engine speed or load.

Fig. 1

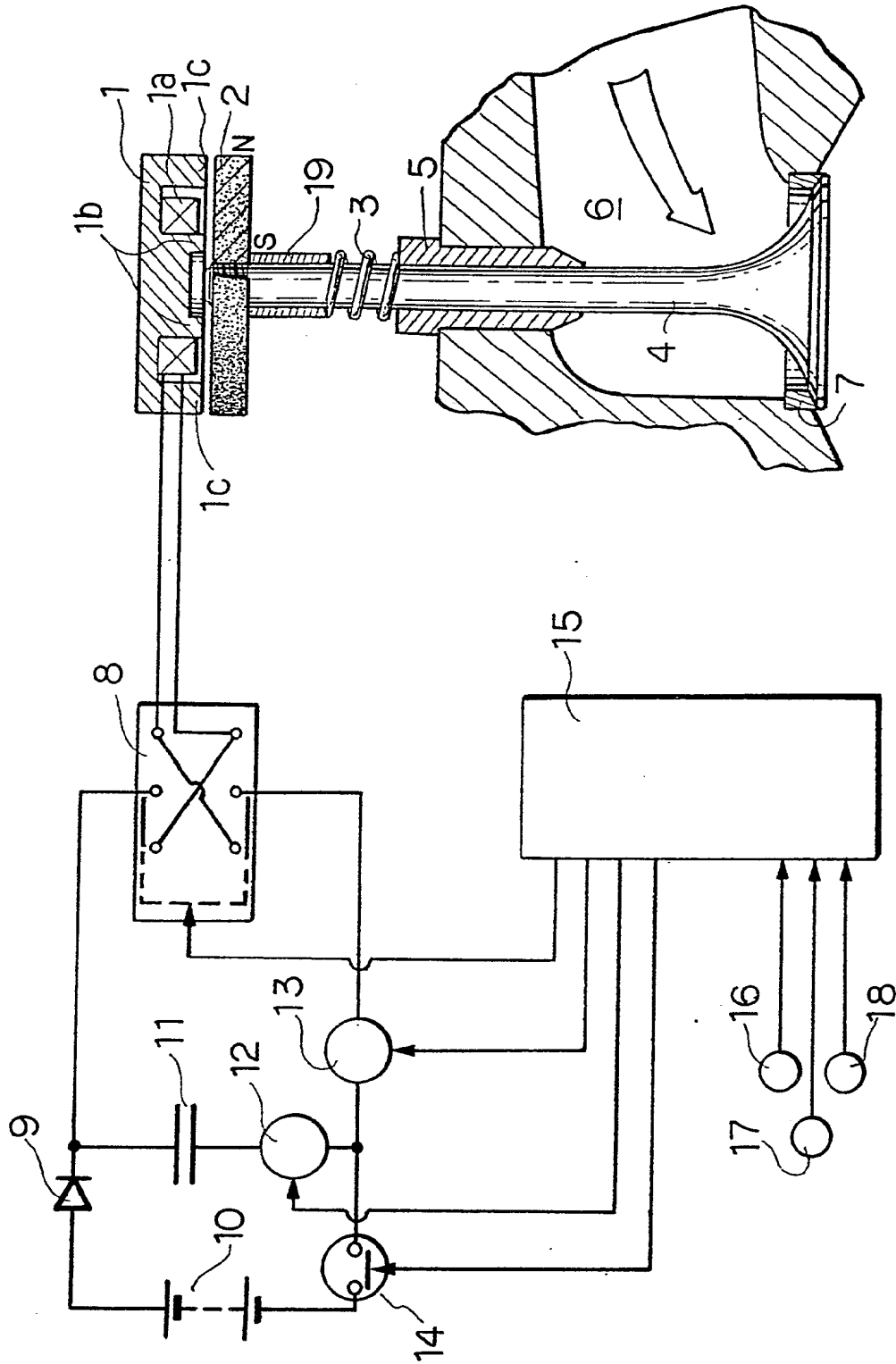


Fig. 2

